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WESTERN SPRUCE BUDWORM SUPPRESSION PROJECT USING BACILLUS THURINGIENSIS BERLINER--1984

Carson National Forest
New Mexico

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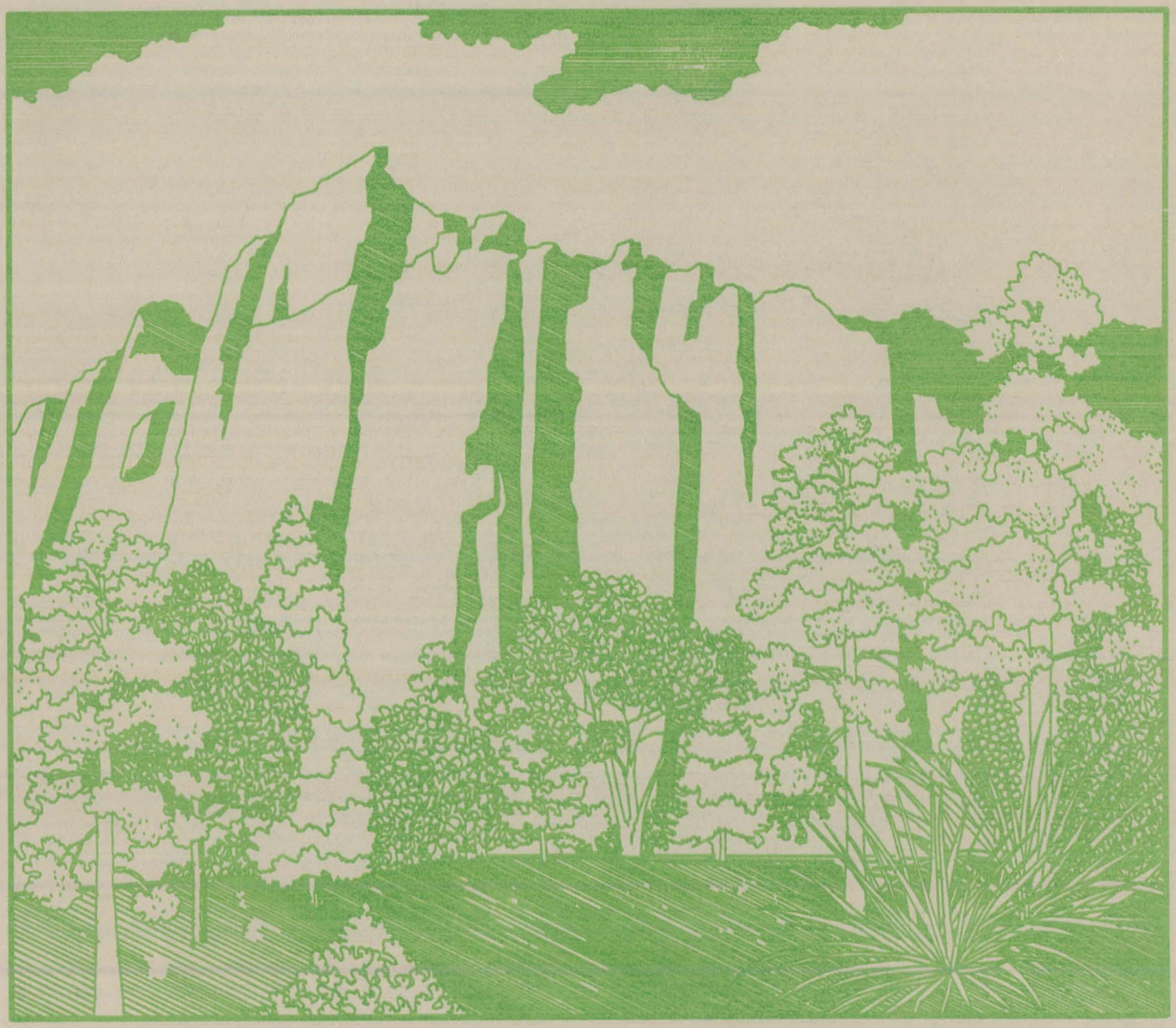

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INTRODUCTION

The western spruce budworm (WSBW), Choristoneura occidentalis Free., was detected on the western half of the Carson National Forest in 1980. Defoliation was first observed on the El Rito Ranger District (El Rito entomological unit) and the Tres Piedras Ranger District (Tres Piedras entomological unit) in 1980 and then on the Canjilon Ranger District in 1982. Acres of host type defoliated on this half of the Forest to date include 1,850 acres in 1980, 8,700 acres in 1981, 38,300 acres in 1982, 62,350 acres in 1983, and 101,800 acres in 1984.

In 1982 and 1983, a total of 73,300 acres of budworm-infested host type was aerially sprayed with carbaryl and the bacterium Bacillus thuringiensis (B.t.) to control and prevent the further spread of this outbreak. Carbaryl was applied to the majority of the infested host type and B.t. primarily to ecologically sensitive areas. Overall, prespray budworm population densities were effectively reduced to 5 or fewer larvae per 100 buds necessary to achieve foliage protection the year following treatment (Telfer, Linnane, and Davis 1983; Telfer and Linnane 1984). However, because new areas of budworm defoliation were detected during the summer of 1983, approximately 34,600 additional acres of budworm-infested host type were treated with B.t. in 1984. This report documents the objectives, operational aspects, sampling procedures, and results of this 1984 WSBW suppression project.

OBJECTIVES

Objectives of this project were to:

1. Reduce WSBW populations to 5 larvae per 100 buds or less so that (a) predators and parasites, in conjunction with density independent factors, such as weather, could further reduce insect numbers; and (b) tree damages would be reduced.

2. Evaluate the operational effectiveness of B.t. applied at reduced dilution rates.

PROJECT ORGANIZATIONAL STRUCTURE

Personnel from the Carson National Forest administered the 1984 WSBW project with assistance of personnel from Forest Pest Management, State and Private Forestry, Southwestern Region (figure 1, appendix). With the exception of the project entomologist and field technician and respective field crews who worked out of the Tres Piedras Ranger District Office, all remaining personnel and air and ground support groups were headquartered at the Taos Airport, Taos, New Mexico.

INSECTICIDE FORMULATION

B.t. (Thuricide 32 LV) was applied at 12 billion international units per acre. B.t. was applied 64 ounces (3 parts B.t.: 1 part water) per

acre on 31,070 acres, and at 48 ounces (neat=undiluted) per acre on 3,467 acres. B.t. has been extensively tested against the WSBW in the Southwest with varying success. In 1981, a pilot test using B.t. in New Mexico produced satisfactory results leading to the decision to use B.t. operationally in 1983 (Ragenovich 1983).

SPRAY BLOCKS

The treatment area (figure 2, appendix) was divided into five spray blocks. B.t. was applied at 64 ounces per acre on spray blocks 1, 3, 4, and 5, and at 48 ounces on spray block 2. Individual spray blocks treated with 64 ounces per acre are not replications of a particular treatment, but represent units that were sprayed during a typical, operational spray day. Each of the spray blocks were laid out taking into account aspect and elevational differences to insure that both foliage development and budworm larval development were as uniform as possible and that spray block boundaries were easily recognizable from the air. Individual spray blocks are listed in table 1 along with block name, acres, and date sprayed.

TABLE 1.--1984 WSBW suppression project spray blocks

Spray block number	Spray block	Acres sprayed	Date sprayed
1	La Jara - Tio Grande East	7,950	June 21
2	Los Pinos	3,467	June 22
3	Alire Spring - Lola Spring	8,640	June 23
4	Burned Mountain	8,640	June 24
5	Olguin Mesa - Tio Grande West	5,840	June 25
	Total acres sprayed	34,537	

TIMING OF SPRAY APPLICATION

Timing of spray application was based on a combination of foliage development and budworm larval development. B.t. was aerially applied when the current year's foliage was sufficiently flushed and when 50 percent of the budworm larval population was in the fourth and fifth instars. Larval development at the time of treatment was determined from prespray samples and is summarized below (table 2):

TABLE 2.--Percent WSBW larval development by instar at time of treatment for 1984 spray blocks

Spray block number	II	III	IV	V	VI	Pupae
1	1.3	5.3	33.2	47.9	12.3	--
2	0.4	7.5	29.2	50.0	12.9	--
3	3.8	14.8	46.2	24.8	10.4	--
4	4.1	24.7	57.6	12.7	0.9	--
5	1.1	6.5	29.4	52.4	10.6	--

WEATHER FORECASTING AND MONITORING

Local weather forecasts were provided each day to the project director. These forecasts were obtained by the project meteorologist from the National Weather Service Office in Albuquerque, New Mexico. National Oceanic and Atmospheric Administration meteorologists used onsite weather data collected the previous day and telephoned to Albuquerque to adjust their forecast to local situations.

SPRAY APPLICATION

Characterization. Spray characterization trials were conducted in Litchfield Park, Arizona, during April 10-12, 1984. The trial objective was to determine an effective B.t. dilution rate, spray nozzle configuration, and nozzle size. The trial design followed methods described by Dumbauld and Rafferty (1977), principally the collection and assessment of droplet density and volume median diameter (VMD) data. Dipel 6L (Abbott Laboratories)[1] and Thuricide 32 LV (Zoecon Corporation) were assessed at various dilution rates, nozzle configurations, and nozzle sizes. A Marsh Turbo-Thrush aircraft equipped with an airfoil boom and pressure nozzles with flat fan tips was the trial aircraft (figure 1).

The characterization trial results for Thuricide 32 LV are presented in appendix, table 1. At 12 BIU per acre, trials were conducted for 96 ounces per acre (1 part B.t. to 1 part water), 64 ounces per acre (3 parts B.t. to 1 part water), and 48 ounces per acre (undiluted) application rates with various nozzle conifigurations.

Characterization trial results indicated B.t. can be effectively applied at 64 ounces and 48 ounces per acre rates. For the 64 ounces per acre application rate, 8008 flat fan nozzles oriented straight down gave an adequate VMD and droplet density. For the 48 ounces per acre application rate, 8008 flat fan nozzles oriented 45° forward appeared best. The VMD for this rate could not be determined for lack of a suitable spread factor.

The characterization trials were conducted with the assistance and cooperation of Forest Pest Management, Davis, California, the Zoecon Corporation, and Abbott Laboratories.

Application Strategy. B.t. was applied at 12 BIU per acre at a rate of 64 ounces per acre or 48 ounces per acre approximately 50 feet above the tree canopy. The spray applications were scheduled for the early morning hours shortly after sunrise when meteorological conditions were optimum. Spray operations were canceled when wind or air temperature caused unmanageable spray drift.

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[1]The insecticide Dipel 6L was applied as part of the 1984 Lincoln/Mescalero western spruce budworm suppression project.

FIGURE 1.--Marsh Turbo-Thrush equipped with airfoil boom during characterization trials, Litchfield Park, Arizona

The insecticide was applied by four, turbine-powered, fixed-wing Air Tractor 400 aircraft. These aircraft were equipped with airfoil spray booms and wind-driven pumps. The spray delivery system utilized pressure nozzles with flat fan tips. Air Tractor 400's have a 400-gallon hopper capacity.

All four aircraft operated in a single formation with orientation and guidance provided by Forest Service observers in two helicopters. The helicopters were stationed at opposite ends of a spray swath. Through radio communications, observers directed the spray aircraft's heading, maintained proper swath width, and assured aircraft released the insecticide within the appropriate treatment boundaries. The observation helicopters were both Bell 206 Jet Rangers.

FIGURE 2.--Turbine-powered, fixed-wing Air Tractor 400 aircraft in single formation

Calibration. All four spray aircraft were calibrated to deliver 64 ounces per acre immediately prior to the start of the spray program. The lead aircraft was recalibrated to deliver 48 ounces per acre prior to the undiluted application. Nozzles were removed from the remaining aircraft based on calibration data from the lead plane. The lead aircraft was equipped with an onboard flowmeter which greatly assisted in calibration. For calibration, aircraft ground speed was estimated at 140 miles per hour. Swath width was 150 feet.

Mixing and Loading. Insecticide mixing and loading took place at the Taos Airport. All necessary equipment and labor were provided by the contractor. This included two trailer-mounted, 6,000-gallon storage tanks, two 1,500-gallon mix tanks, and necessary pumps, hoses, and flowmeters. For the 64 ounces per acre applications, Thuricide was diluted and mixed the day prior to application, provided the weather forecast was favorable. The aircraft were loaded in the morning just prior to takeoff. The 48 ounces per acre (undiluted) application required no mixing and the aircraft were loaded in the morning. The Air Tractor 400 easily handled 350 to 370 gallons of diluted or 325 gallons of undiluted Thuricide 32 LV. The Taos Airport is located at 7,986 feet above sea level. A normal spray day consisted of approximately 3 hours. The Air Tractor 400's required slightly less than 1 hour to load, ferry, and spray 325 to 370 gallons of insecticide. The treatment blocks were 35 to 50 miles from the airport.

Spray operations commenced June 21, 1984, and were completed on June 25, 1984. Operations began at sunrise and were usually terminated by 0900. Spray operations were canceled prior to 0900 if unmanageable spray drift was encountered. Table 1 summarizes the acreage and treatment blocks sprayed by day.

SPRAY DEPOSIT ASSESSMENT

A spray deposit assessment, using white Kromekote cards, was undertaken, principally, to determine if sampling points were treated. In the morning prior to spraying, two cards were placed in a clearing near each three-tree cluster sampling plot. When possible, cards were placed at least one tree height in distance from adjacent trees so as not to be in the spray shadow of nearby trees. Cards were collected immediately after spraying for spray deposit evaluation. The number of spray droplets within a four-square centimeter area was estimated. The mean number of spray droplets per square centimeter was then determined for each card and averaged for each plot. An overall average was then determined for each spray block.

EVALUATING PROJECT EFFECTIVENESS

Effectiveness of the pesticide treatments was determined by comparing pre- and post-spray larval densities. Larval population densities were sampled 1 to 2 days prior to treatment and again 21 days after treatment. Pesticide treatments were considered successful if larval population densities were reduced to 5 or fewer larvae per 100 buds, the established criterion for success stated in the objectives.

Egg mass surveys were conducted in August to provide an indication of larval density and defoliation trends expected to occur in 1985. Egg mass samples were collected from a total of 96 plots randomly scattered throughout the 5 spray blocks following Region 3 standardized sampling procedures (Ragenovich 1983).

The sampling design consisted of pre- and post-spray sampling plots. Sample plots were .2 miles apart and, because of available road access in each block, ranged between 14 and 27 sample plots. Each sample plot consisted of a three-tree cluster of Douglas-fir trees. The three trees were located within 1 acre. One branch was sampled per tree for prespray estimates and two branches per tree were sampled for postspray estimates.

The plot constituted the primary sampling unit. Plot means were computed by averaging the larvae per 100 buds for each branch(es) sampled and then averaging the three-tree cluster. Larval means and standard errors were then calculated for each spray block and are summarized in table 1, appendix.

RESULTS AND DISCUSSION

Spray Blocks 1, 3, 4, and 5

WSBW infestations on these spray blocks which totaled 30,070 acres, were aerially sprayed with 12 BIU's of B.t. at an application rate of 64 ounces per acre. Kromekote spray deposit cards placed near each sample plot indicated all plots monitored were treated. Spray deposit densities were fairly uniform on spray blocks 1, 3, and 4, averaging 11.2, 9.9, and 8.9 droplets per cm^2, respectively. Spray deposit densities were somewhat higher on spray block 5 which averaged 21.7 droplets per cm^2. The overall combined average for these spray blocks was 11.6. These data are summarized in table 3.

With the exception of one spray block, prespray budworm larval population densities were exceptionally high (table 4). Average prespray densities for individual blocks ranged from 22.7 to 58.2 and averaged 41.1 larvae per 100 buds overall. A visual examination of the sample trees indicated 2 to 3 years of light to moderate defoliation, sufficient time for epidemic levels of budworm to build up.

Larval population densities 21 days after treatment decreased 69 percent (table 4). Percent reduction for individual spray blocks ranged from 52 to 84 percent. Residual postspray population densities averaged 4.6 larvae per 100 buds on spray block 1, but ranged from 9.1 to 22.7 on spray blocks 3 to 5. These unacceptably high postspray population densities on blocks 3 to 5 may have resulted in part because prespray densities were already at outbreak levels and also because evening rain showers occurred subsequent to spraying blocks 3 and 4. These rain showers may have significantly reduced the effectiveness of B.t. on these blocks. Postspray densities on these two blocks averaged 15.5 and 22.7 larvae per 100 buds, respectively.

TABLE 3.--Summary of average spray droplet densities per cm^2 for individual spray blocks

Block Number	N.	Application rate	Average droplets/cm^2
1	12	64 ounces/acre	11.2 ± 1.3
3	16	64 ounces/acre	9.9 ± 2.1
4	27	64 ounces/acre	8.9 ± 1.2
5	11	64 ounces/acre	21.7 ± 2.0
	Σ=66		$\Sigma\bar{x}$ 12.9 ± 2.9
2	11	48 ounces/acre	5.5 ± 20

TABLE 4.--Mean WSBW larval densities per 100 buds for pre- and post-spray samples and percent mortality

Spray block number	Number of plots	Larvae per 100 buds		Percent mortality (unadjusted)
		Prespray	Postspray[1]	
1	34	$\bar{x}$ = 22.7 S.E. = 2.9	$\bar{x}$ = 4.6 S.E. = 0.6	80%
3	20	$\bar{x}$ = 46.9 S.E. = 4.2	$\bar{x}$ = 22.7 S.E. = 2.1	52%[2]
4	27	$\bar{x}$ = 36.6 S.E. = 2.5	$\bar{x}$ = 15.5 S.E. = 1.4	58%[2]
5	11	$\bar{x}$ = 58.2 S.E. = 7.3	$\bar{x}$ = 9.1 S.E. = 1.1	84%
	Σ=92	$\Sigma\bar{x}$ = 41.1 S.E. = 7.6	$\Sigma\bar{x}$ = 12.9 S.E. = 3.9	$\Sigma\bar{x}$ = 69% S.E. = 7.9
2	11	$\bar{x}$ = 48.8 S.E. = 7.5	$\bar{x}$ = 9.2 S.E. = 1.5	81%

[1]21-day postspray sample
[2]Rain showers subsequent to spraying may have significantly reduced the effectiveness of *B.t.* on these blocks.

Based on egg mass surveys conducted shortly after adult budworm moth flight was completed, defoliation and tree damages are expected to continue throughout these spray blocks in 1985. Average egg mass densities (summarized in table 5) ranged from 8.7 to 15.9 egg masses per meter^2 of foliage. The combined overall egg mass density averaged 13.6.

Spray Block 2

This spray block consisted of 3,460 acres of infested host type and was sprayed with 12 BIU's of undiluted B.t. at 48 ounces per acre. To insure adequate spray deposition at this reduced volume per acre, the nozzle configuration on each spray plane was reoriented to the 45° forward position to decrease the volume median diameter (VMD) of the spray droplets. Results from the spray deposit data obtained from individual sample plots ranged from 3.3 to 7.6 and averaged 5.5 droplets per cm^2 (table 3). These results, which were significantly lower than expected, may have been caused by evaportion of the smaller droplets, drift due to thermal convections, and/or sampling error.

All infested trees sampled on this block were defoliated for up to three consecutive years. Prespray larval densities were also exceptionally high on this block, averaging 48.8 larvae per 100 buds. Prespray densities for individual plots sampled ranged from 16.7 to 94.6 larvae per 100 buds. Although larval densities decreased significantly 21 days after treatment (table 4), residual postspray population densities remained at outbreak levels, averaging 9.2 larvae per 100 buds. Egg mass densities were high, averaging 22.7 egg masses per meter^2 of foliage. These data indicate that the WSBW will continue to cause noticeable defoliation and tree damages throughout this spray block in 1985.

TABLE 5.--Average egg mass densities per m^2 of foliage

Spray block number	N.	Average egg masses/m^2
1	35	8.7 ± 1.4
3	24	15.9 ± 7.2
4	15	14.9 ± 3.8
5	11	15.0 ± 5.0
	Σ=85	$\Sigma\bar{x}$ 13.6 ± 1.7
2	11	22.4 ± 7.2

PROJECT COST SUMMARY

Table 6 summarizes actual expenditures including salaries, vehicle use, and supplies contributed by FPM. Total project cost was $245,855.37 or $7.11 per acre.

TABLE 6.--Project cost summary

Insecticide	Item cost (dollars)	Total cost (dollars)
B.t. (13,125 gallons)	124,687.50	124,687.50
Application		
Aircraft	50,170.00	
Helicopters	27,000.00	
Reconnaissance	379.60	
Safety inspection	491.15	
		78,040.75
Supplies	6,484.54	6,484.54
Overhead: salaries, overtime, and travel		
Carson National Forest	10,132.00	
Forest Pest Management	9,225.06	
		19,357.06
Miscellaneous cost		
Vehicles, etc.	3,783.52	3,785.52
	Total project cost:	245,855.37
	Treatment cost per acre:	7.11

CONCLUSIONS

Overall, the results obtained from this 1984 WSBW suppression project were unsatisfactory. The primary objective of this project, which was to reduce larval population densities to 5 or fewer larvae per 100 buds, was achieved on only 1 of the 5 blocks treated. Residual postspray densities on 4 of the 5 spray blocks sprayed remained at epidemic levels, averaging 9.1 or more larvae per 100 buds. Because of the high reproductive potential of the WSBW, these postspray larval densities are expected to increase to prespray levels within a year or two unless they are re-treated again in 1985. These unacceptably high residual postspray densities indicate that the effectiveness of B.t. is significantly diminished when used to suppress high WSBW population

densities, i.e., average population densities of 30 or more larvae per 100 buds. In addition, the overall effectiveness of B.t. was probably severely impacted by evening rain showers which occurred subsequent to spraying blocks 3 and 4. Postspray population densities on these 2 blocks averaged 22.7 and 15.5 larvae per 100 buds 21 days after treatment, respectively.

The second objective of this project was to evaluate the operational effectiveness of lower dilution rates in reducing WSBW populations to very low levels, i.e., to 5 or fewer larvae per 100 buds. The results obtained from this project showed no significant differences between average postspray larval densities obtained for blocks 1, 3, 4, and 5 treated at 64 ounces per acre and block 2 treated at 48 ounces per acre. With the exception of block 1, which was reduced to 4.6 larvae per 100 buds, residual postspray population densities, regardless of the volume per acre, remained at epidemic levels, averaging 9.1 or more larvae per 100 buds. The overall effectiveness of B.t. on blocks 2 to 5 was probably masked by the prohibitively high prespray densities which averaged 36.6 or more larvae per 100 buds on these blocks. B.t. is generally not recommended for use against very high WSBW population densities. Prespray budworm densities on block 1 were within the established range for successful control (Ragenovich 1983), averaging 22.7 larvae per 100 buds.

Based on the egg mass surveys conducted shortly after the adult budworm flight period was completed, defoliation and tree damages resulting from the WSBW are expected to continue throughout the 1984 project area in 1985.

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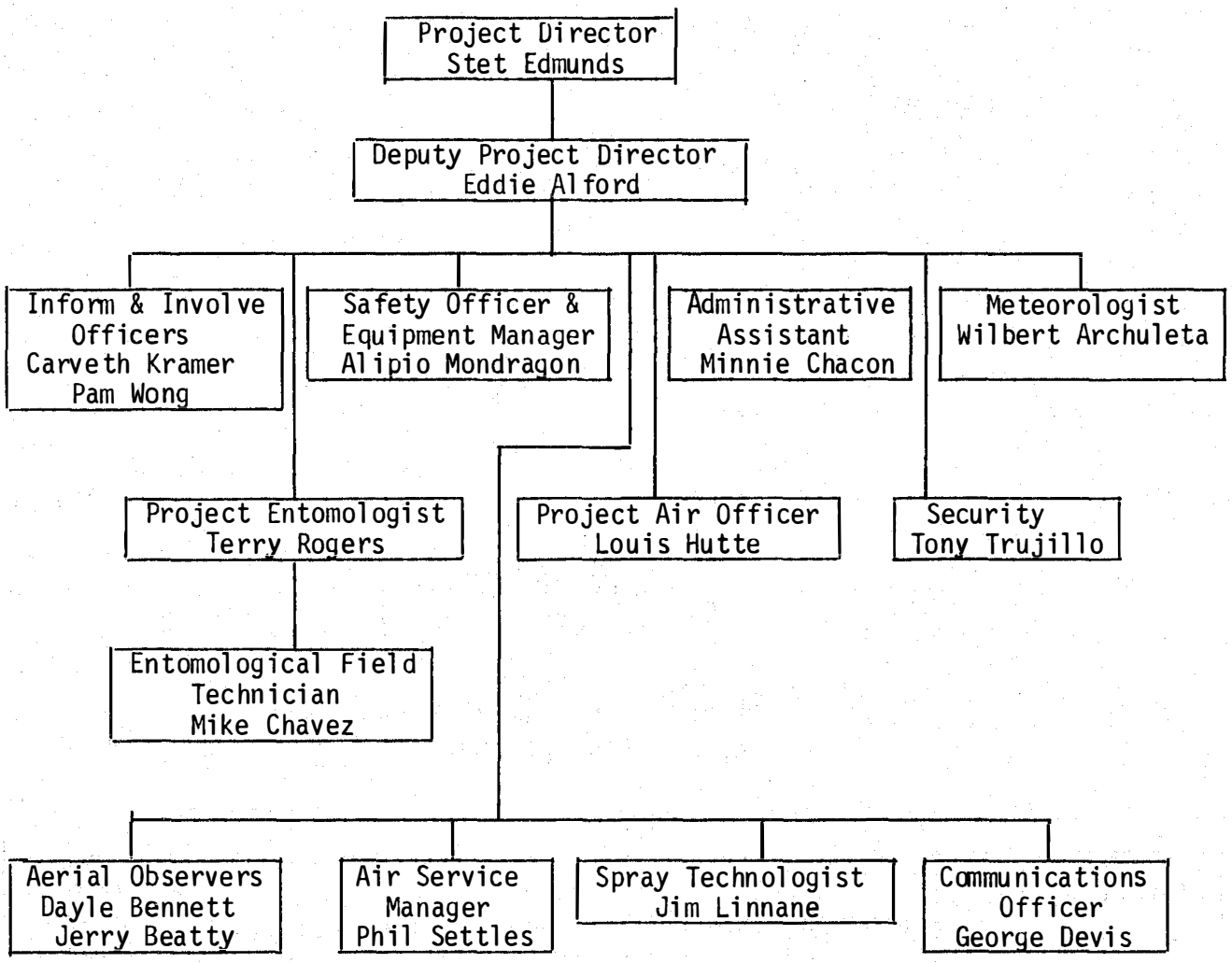
APPENDIX

FIGURE 1.--Project organization chart



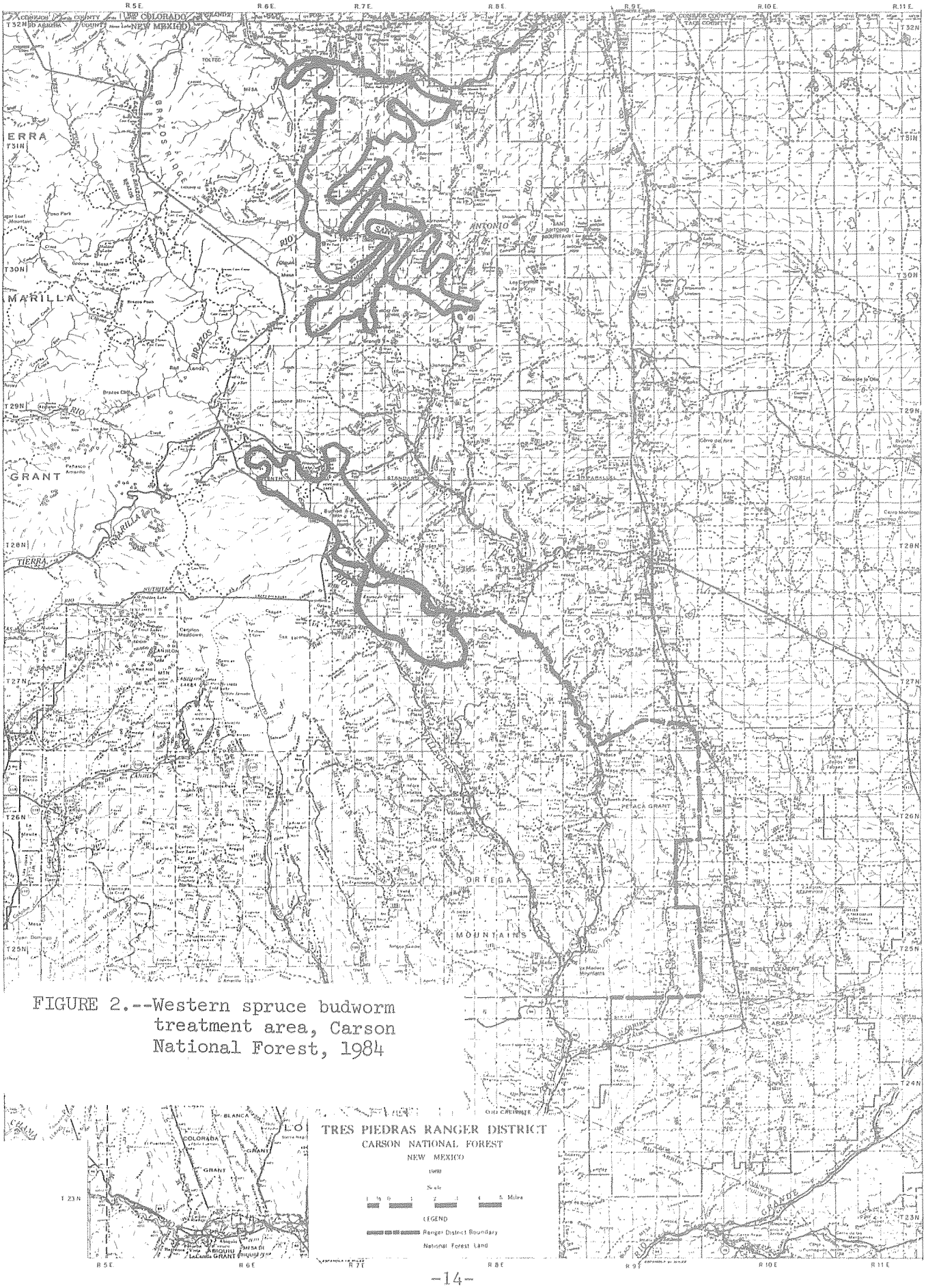


FIGURE 2.--Western spruce budworm treatment area, Carson National Forest, 1984

TABLE 1.--Spray characterization of Thuricide 32 LV applied with Marsh Turbo-Thrush. Trials conducted at Litchfield Park, Arizona, April 11-12, 1984

Trial	Tank mix	Aircraft[1]		Meteorology			Deposit data				Nozzle	
		Speed (mi/h)	Release height (ft)	Temp (°F)	RH (%)	W/S (mi/h)	VMD (μm)	Drops/ cm²	Oz/ acre	Swath width (ft)	Type	Orientation
19	Neat 48 oz/acre[2]	150	50	58	47	5		16		230	8008	Straight down
20	Neat 48 oz/acre[2]	150	50	60	49	4	N/D[3]	12	N/D	300	8008	Straight down
21	Neat 48 oz/acre[2]	150	50	64	35	5		24		210	8008	45° forward
22	1 part Thuricide to 1 part water 96 oz/acre	150	50	68	32	3	95	22	11	250	8010	Straight down
23	"	150	50	70	34	2	93	10	5	330	8010	Straight down
14	3 parts Thuricide 1 part water 64 oz/acre	150	50	68	24	2	113	18	10	250	8008	Straight down
15	"	150	50	70	25	2	98	16	7	280	8008	Straight down
16	"	150	40	56	N/D	3	146	27	19	230	8008	Straight down
17	"	150	40	55	44	5	115	18	12	250	8008	Straight down
18	"	150	40	56	45	4	96	26	11	250	8008	45° forward

[1]Boom pressure 40 psig.
[2]VMD and oz/acre could not be determined for lack of a suitable spread factor for undiluted (neat).
[3]N/D = no data

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honeybees or other pollinators are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the label.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

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